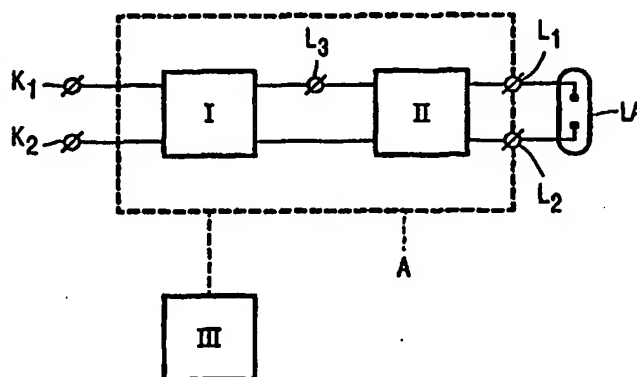




## INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

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(54) Title: CIRCUIT ARRANGEMENT



## (57) Abstract

The invention relates to a circuit arrangement for operating a high pressure discharge lamp with a lamp current having successive periods of opposite polarity, which lamp is provided with at least two main electrodes being placed on an electrode distance from each other, the circuit arrangement comprising: input terminals for connecting a supply source, output terminals for connecting the high pressure discharge lamp, and means, coupled to the input terminals, for supplying the lamp current to the high pressure discharge lamp of which the successive periods have a predetermined shape. According to the invention the circuit arrangement is provided with means for detecting a first parameter indicative for the electrode distance and forming a first signal dependent on the first parameter, means for reshaping of the periods of the lamp current in dependence of the thus formed first signal.

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## Circuit arrangement.

The invention relates to a circuit arrangement for operating a high pressure discharge lamp with a current having successive periods of opposite polarity, which lamp is provided with at least two main electrodes being placed on an electrode distance from each other, the circuit arrangement comprising:

- 5 -input terminals for connecting a supply source,
- output terminals for connecting the high pressure discharge lamp, and
- means, coupled to the input terminals, for supplying the lamp current to the high pressure discharge lamp of which the successive periods have a predetermined shape.

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Such a circuit arrangement is known from the American Patent 5,608,294. The known circuit arrangement provides a measure to suppress flickering of a high pressure discharge lamp and is in particular suitable for operating a high pressure discharge lamp in a projection system like a projection television apparatus. In the known circuit arrangement, the lamp is

15 supplied with a current of successive block shaped periods of opposite polarity. The suppression of flickering is reached by supplying to periods of the lamp current an additional current pulses with the same polarity at the end of a predetermined fraction of such a period of the lamp current. By means of the thus reshaped current period, the temperature of the electrode is raised to a relatively high value, which high temperature increases the stability of

20 the discharge arc, because the discharge arc originates from the same place on the electrode in each cathodic phase and so flickering is substantially suppressed. The additional current is supplied in a regular sequence, preferably at each successive pulse. Although it is known that AC operation of high pressure discharge lamps with a low frequency alternating lamp current prevents a rapid erosion of the electrodes of the high pressure discharge lamp (further also

25 referred to as the lamp) and allows operation of the lamp with a relatively high efficacy, it has occurred that lamps operated with the known circuit arrangement showed to have a continuous increase of the arc voltage over an operating time of several hundred hours, which voltage increase appeared to continue when the lamp was experimentally operated for several thousand hours. As a luminous output of the lamp being fairly constant over the life of the

lamp is of vital importance for use in a projection system, a continuous arc voltage increase forms a serious drawback in reaching a long lamp life.

In case a high pressure discharge lamp is operated with an AC current, each electrode of the lamp alternately functions as a cathode and as an anode during successive periods of the lamp current. During these periods the electrode is said to be in the cathodic phase and the anodic phase respectively. Electrode material, that is removed from the electrode in the anodic phase, returns to the electrode as a stream of ions in the cathodic phase. These transport processes further complicate the behaviour of the electrode temperature during each period of the lamp current since the time dependency of the electrode temperature in the anodic phase differs from that in the cathodic phase.

The invention aims to provide a circuit arrangement for operating a high pressure discharge lamp in a way which substantially overcomes the mentioned drawback and simultaneously is maintaining the substantial suppression of flickering of the lamp during its operation.

According to the invention, a circuit arrangement of the kind mentioned in the opening paragraph is for this purpose characterized in that that the circuit arrangement is provided with

- means for detecting a first parameter indicative for the electrode distance and forming a first signal dependent on the first parameter, and with
- means for reshaping of the periods of the lamp current in dependence of the thus formed first signal.

It has surprisingly occurred that with a controlled reshaping of the periods of the lamp current it is possible to substantially overcome the problem of continuous increase of the lamp voltage without significantly violating lamp flicker suppression.

Further improvement with regard to discharge arc stability is preferably achieved when the circuit arrangement further comprises:

- means for detecting a second parameter indicative for the occurrence of lamp flicker and forming a second signal dependent on the detected second parameter, and
- means for a further adjustment of the shape of the successive periods in dependence of the thus formed second signal.

Because the shape of the current flowing through the lamp is changed in accordance with the detection of occurrence of flickering, it has advantageous appeared possible to suppress both the flickering to an level fully acceptable for optical projection and simultaneously substantially control alterations in the electrode distance and thus counteract a continuous tendency of lamp voltage increase.

In an embodiment the first parameter is formed by the lamp voltage, preferable averaged over several periods.

In an embodiment of the circuit arrangement according to the invention the lamp voltage during each successive period is providing for the second parameter. Use of the lamp voltage for forming the second parameter has as advantage that for first and second parameter the same quantity is used. This simplifies the circuit arrangement. In a first preferred embodiment the shape of the lamp voltage during each period is detected and used for forming the second parameter. Preferable this is realized by means in the circuit arrangement which measure the lamp voltage at selected intervals during such a period and compare the thus found values with each other. In a second preferred embodiment for forming the second parameter it is the value of the lamp voltage in successive periods at a fixed moment during each period, preferably at a moment of a constant lamp current, which are detected. In a practical embodiment this is preferable realized by means measuring the lamp voltage at a moment close to the end of each period and comparing the outcome of consecutive periods having the same polarity. In a further embodiment the second parameter is formed by the luminous output of the lamp, for instance by means of optical detectors placed around a display area of a projection system, for instance at the edge of the display area.

Good results were obtained in case the frequency of the periods of opposite polarity of the lamp current was selected from the range 45 Hz - 500 Hz.

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The above and further aspects of the invention will be explained in more detail below with reference to a drawing, in which

Fig. 1 shows an embodiment of a circuit arrangement according to the invention;

Fig. 2 shows control means of an embodiment of a circuit arrangement according to the invention in accordance with fig 1;

Fig. 3 shows control procedure as prosecuted by the embodiment according to fig 2;

Fig. 4 shows a flicker control loop forming part of the control procedure according to fig 3, and

Fig. 5 to 10 showing different shapes of successive periods forming the lamp current provided by the circuit arrangement according to fig 1,

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In Fig. 1, K1 and K2 denote input terminals for connection to a supply voltage source supplying a supply voltage. I, coupled to K1 and K2, are means for generating a DC supply current. Output terminals of means I are connected to respective input terminals of commutator II. Output terminals of commutator II are connected by the high pressure discharge lamp La, which lamp is provided with at least two main electrodes being placed on an electrode distance from each other. III are control means to control the shape of successive periods of opposite polarity of the current supplied to the lamp by way of controlling the means I and incorporate both means for detecting a first parameter indicative for the electrode distance and forming a first signal dependent on the first parameter and means for adapting the lamp current in dependence of the thus formed first signal. Means I and means II together constitute means A, coupled to the input terminals, for supplying the lamp current to the high pressure discharge lamp of which lamp current the successive periods have a predetermined shape.

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The operation of the circuit arrangement shown in Fig. 1 is as follows.

When input terminals K1,K2 are connected to a voltage supply source, means I generate a dc supply current from the supply voltage supplied by the voltage supply source. Commutator II converts this dc current into an alternating current having successive periods of opposite polarity. By control means III the shape of the successive periods of the current thus formed and supplied to the lamp La is controlled. In a practical realization of the described embodiment the means I are formed by a rectifier bridge followed by a switch mode power circuit, for instance a Buck or down converter. Commutator II preferably comprises a full bridge circuit. Lamp ignition circuitry is preferably incorporated also in the commutator means II.

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In Fig. 2, the control means III for controlling means I are shown in more detail. The control means III comprise an input 1 for detecting the lamp voltage, for instance the voltage over the terminals L1,L2 connected to the lamp forming a signal representing the lamp voltage. Preferably the lamp voltage representing signal is formed by detecting a voltage at a connection point L3, as the thus detected voltage is a dc voltage which will not be disturbed by

ignition voltage generated in the lamp ignition circuitry. Control means III further comprises an input 2 for detecting of the current through inductive means L of the converter forming the switch mode power circuit of the means I, which converter has at least a switch, and an output terminal 3 for switching the switch of the switch mode power circuit periodically in a conducting and a non-conducting state thus controlling the current through the induction means L of the converter. Input 1 is connected to connection pin P1 of a microcontroller MC. A connection pin P3 of the microcontroller is connected to an input 4 of a switching circuit SC. Input 2 is connected to an input 5 of the switching circuit SC, of which an output O is connected to output terminal 3. The microcontroller MC are forming means for detecting a first parameter indicative for the electrode distance and forming a first signal dependent on the first parameter as well as means for detecting a second parameter indicative for the occurrence of lamp flicker and forming a second signal dependent on the detected second parameter. The switching circuit forms means for reshaping of the periods of the lamp current in dependence of the thus formed first signal and means for further adjustment of the shape of the successive periods in dependence of the thus formed second signal.

The operation of the circuit arrangement shown in Fig. 2 with the converter being a Buck or down converter, is as follows. The microcontroller MC is provided with software for prosecution procedures as further explained herebelow with reference to figures 3 and 4. The procedures result in a converter peak current value which is fed to switching circuit SC at input 4 and used as reference for comparison for the detected current at input 2 which is also fed to the switching circuit SC, at input 5. Based on this current values comparison the switching circuit generates a switching off signal at output O, which switches the switch of the down converter in the non-conducting state when the detected current equals the peak current value. As a result the current through the inductive means will decrease. The converter switch is kept in the non-conductive state until the current through the inductive means L becomes zero. On detecting the converter current becoming zero the switching circuit SC generates at its output O a switch on signal that renders the switch of the down converter conductive. The current through the inductive means L now starts to increase until it reaches the peak current value. Such switching circuit SC is for instance known from WO97/14275. The value of the peak current is refreshed as outcome of the procedures as prosecuted by the microcontroller MC.

The detection of the lamp voltage is done with a frequency depending on the shape of the current to be realized through the lamp and is controlled by a built in timer of the microcontroller MC. Taking the lamp voltage as lamp parameter for detection has as an

advantage that it makes possible to have a wattage control of the lamp inherently incorporated in the microcontroller software. In case the lamp current itself is taken as parameter for detection a wattage control would not only require an additional detection of the lamp voltage, but also an additional control procedure in the microcontroller. The down converter operates in a favourable embodiment at a frequency in the range of 45kHz to 75kHz.

Fig. 3 shows control procedure as prosecuted by the microcontroller MC of the control means III according to fig 2. A shown voltage control loop VC is started on a regular time basis, for instance once per minute from a flicker control loop FC. From a start SV the driver detects at AA whether the lamp voltage is outside a preferred range. The lamp voltage as supplied via input 1 to connection pin P1 thus forms the first parameter. If the first parameter is not outside the preferred range the control procedure returns to the flicker control loop FC which is explained in detail below. If the lamp voltage is detected at AA to be below a minimum level U- the shape of the successive periods of opposite polarity forming the lamp current, further called mode of operation, is established as stored at B. Too low a lamp voltage indicates that the electrode distance has become too small due to electrode tip growth. The control switches at BI to a next shape of periods from a look up table I which counteracts electrode growth or even promotes electrode distance increase. The new selected shape is stored in B. Then the control procedure returns to loop FC. If the lamp voltage detected at AA is above a maximum level U+ the mode of operation detected at C is switched at CII to a next mode according to a look up table II and the control procedure returns to loop FC. The new selected mode is stored at C. Too high a lamp voltage indicates that the electrode distance has become too large and so the new selected mode is a mode which promotes electrode tip growth. Preferable look up table II is the inverse of look up table I.

The detected voltage values are in case of the described embodiment values of the lamp voltage taken at a fixed moment of each successive period, preferably at the moment .75tp, but at least at a moment that the lamp voltage tends to be stable.

In a diagram shown in fig 4 the flicker control loop FC is illustrated. From a start S the driver detects at F whether flicker is occurring. If so the mode of operation is switched at FIII to a next one according to a look up table III. After a delay period D to let the lamp operation stabilize the control procedure switches to the voltage control loop VC. If no flicker is detected at F it is determined at T if lamp operation is free of flicker for a period > T. If not the control procedure returns to S. Is however the lamp operating flicker free for a period > T than the control procedure forces at FIV the switching over to a next mode of operation according to the look up table IV. After a delay period D to let the lamp operation



stabilize the control procedure switches to the voltage control loop VC. Preferable look up table IV is the inverse of look up table III.

Different shapes of successive periods forming the lamp current defining different modes of operation are hereafter described with reference to fig 5 to 10 for 2 successive periods with opposite polarity. The current is set along the vertical axis in a relative scale. Along the horizontal axis the time is displayed. For a first period TA of time duration  $t_p$  as shown in fig 5 the lamp current has a mean value  $I_m$  and over a first part of the period with time duration  $t_1$  a lower mean value  $I_e$  and over a second part of the period a current  $I_2$  being larger than  $I_m$ . The value of the current  $I_1$  at the beginning of the period  $t_1$  corresponds to a diffuse stable attachment of the discharge to an electrode of the lamp. For flicker free operation it was established that  $.3 \leq I_e/I_m \leq .9$ . In the described embodiment the ratio  $I_e/I_m$  has a value .7 and the ratio  $t_1/t_p$  a value .2.

This mode provides for flicker free operation and also for growth of the electrode tips and so reduction of the electrode distance.

In fig 6 is shown the lamp current of an alternative mode of operation in which the current over the first part of the period is held constant at the value which allows for a diffuse stable attachment of the discharge to the electrodes, herewith defined as thermionic emission of the electrode. Therefore the mean value of the current over this first part  $I_e$  is at most equal to the maximum current that could be supplied by the electrodes through thermionic emission.

This mode provides for flicker free operation and also for growth of the electrode tips and so reduction of the electrode distance.

According to a further preferred mode the resulting current is shown in fig 7. In this case the current  $I_1$  at the start of the period is higher than  $I_e$ .

Also this mode provides for flicker free operation and also for growth of the electrode tips and so reduction of the electrode distance.

In fig 8 is shown a graph of the current according to another mode of operation in which the lamp current is provided with a pulse of the same polarity at the end of the period with a value  $I_3$ . For fulfilling the object of stable operation (flicker free) it has been established that the requirements  $1.4 \leq I_3/I_m \leq 4$  and  $.02 \leq t_3/t_p \leq .25$  should be fulfilled, in which  $t_3$  is the pulse width. In a practical realization of the described embodiment the value of  $I_3$  is  $1.6I_m$ . From experiments it has been deduced that  $I_3$  is preferable chosen in the range  $1.6 \leq I_3/I_m \leq 3$ .

For causing lamp voltage reduction with a current shape according to fig 8 it has been established that  $.02 \leq t_3/t_p \leq .25$  and  $t_2/t_p \geq .5$  are fulfilled. Best results are achieved if  $t_2/t_p \geq .75$ . Preferably  $t_p$  fulfils the relation  $t_p = t_2 + t_3$  with  $.06 \leq t_3/t_p \leq .12$ .

In fig 9 is shown a current shape which is suitable for increasing the lamp voltage. Here the following relations should apply:  
 $I_2 = I_1$ ;  $1.3 \leq I_3/I_m \leq 4$ ;  $0 \leq t_2/t_p \leq .98$ ;  $.02 \leq t_3/t_p \leq .25$ . Herein  $t_2$  is the time lapse between start of the period and start of the additional current pulse.

A current shape as shown in fig 10 in which an additional current pulse of opposite polarity is applied, is also suitable for causing lamp voltage increase. The necessary relation to be fulfilled are:

$I_1 = I_2$ ;  $.1 \leq I_3/I_m \leq .7$ ;  $.5 \leq t_2/t_p \leq .98$ ;  $.02 \leq t_3/t_p \leq .25$ . Particular when the current at the end of the period  $p$  is smaller than  $I_m$  the current shape is effective for lamp voltage increase.

A practical embodiment of a circuit arrangement as shown in Fig. 1 has been used for the operation of a high pressure discharge lamp of the type UHP, make Philips. The lamp had a nominal power consumption of 100 Watt and an electrode distance of only 1.4 mm, was operated with two different modes of operation defining different shapes of successive periods forming the lamp current. In a first mode of operation the successive periods of opposite polarity are shaped as shown in fig 9. The value of the current in this mode corresponding to  $I_1$  is regulated by way of a wattage control incorporated in the microcontroller software to a nominal value of 1.06A. The maximum value for  $I_3$  is fixed at 2.5A. The period duration  $t_p$  is 5.6ms, according to a operating frequency of the commutator means  $I_1$  of 90Hz, and the ratio  $t_3/t_p$  is controlled to be 0.08 with  $t_2 + t_3 = t_p$ . As long as the lamp voltage, having a nominal value of 85V, is above 68V the current  $I_3$  is fixed at 2.5A. In case the detected lamp voltage has decreased to 68V the periods are reshaped by the means A in that the current  $I_3$  is stepped down in 3 steps to the value of  $I_1$ , after which the means A switch over to a second mode of operation in which the supplied lamp current is formed by periods which are shaped as rectangular blocks with a value controlled with the same wattage control as mentioned for the first mode at the same nominal value as  $I_1$ . Thus the voltage minimum level  $U_-$  is 68V. For the voltage maximum level  $U_+$  a value of 110V is used. As microcontroller MC a P87C749EBP, make Philips has shown to be suitable when programmed to detect the lamp voltage once at a fixed moment during each period, preferably at  $0.75t_p$ .

The thus detected lamp voltage is also forming the second parameter. The found values of successive period of equal polarity are compared for detecting occurrence of discharge attachment on the electrodes tending to become unstable and used as defining lamp

flicker. For a thus found voltage difference a value of  $>1\text{ V}$  occurring more than once over a time span of 2 minutes is set in the software as threshold for the occurrence of lamp flicker. In a further practical embodiment the detection of occurrence of lamp flicker is based on comparison of the found voltage differences of the detected voltages with 3 different thresholds each connected to a separate repetition rate as to detect both lamp flicker of high and of low frequency with high accuracy. The values of the thresholds and corresponding repetition rate is given in a table.

Table

10

Voltage value in V	Repetition rate in s
1	120
0.3	30
0.1	5

## CLAIMS:

1. Circuit arrangement for operating a high pressure discharge lamp with a current having successive periods of opposite polarity, which lamp is provided with at least two main electrodes being placed on an electrode distance from each other, the circuit arrangement comprising:
  - 5 -input terminals for connecting a supply source,
  - output terminals for connecting the high pressure discharge lamp, and
  - means, coupled to the input terminals, for supplying the lamp current to the high pressure discharge lamp of which the successive periods have a predetermined shape, characterized in that the circuit arrangement is provided with
  - 10 -means for detecting a first parameter indicative for the electrode distance and forming a first signal dependent on the first parameter, and with
  - means for reshaping of the periods of the lamp current in dependence of the thus formed first signal.
- 15 2. Circuit arrangement according to claim 1, wherein the circuit arrangement further comprises:
  - means for detecting a second parameter indicative for the occurrence of lamp flicker and forming a second signal dependent on the detected second parameter, and
  - means for a further adjustment of the shape of the successive periods in dependence of the
  - 20 thus formed second signal.
3. Circuit arrangement according to claim 1 or 2 characterized in that the first parameter is formed by the lamp voltage.
- 25 4. Circuit arrangement according to claim 1,2 or 3 characterized in that the second parameter is formed by the lamp voltage during successive current periods.
5. Circuit arrangement according to claim 4 characterized in that the lamp voltage at each period has a shape which is detected.

6. Circuit arrangement according to claim 4 characterized in that the lamp voltage at each period has a value which is detected.
- 5 7. Circuit arrangement according to claim 1,2 or 3 characterized in that the second parameter is formed by the luminous output of the lamp.



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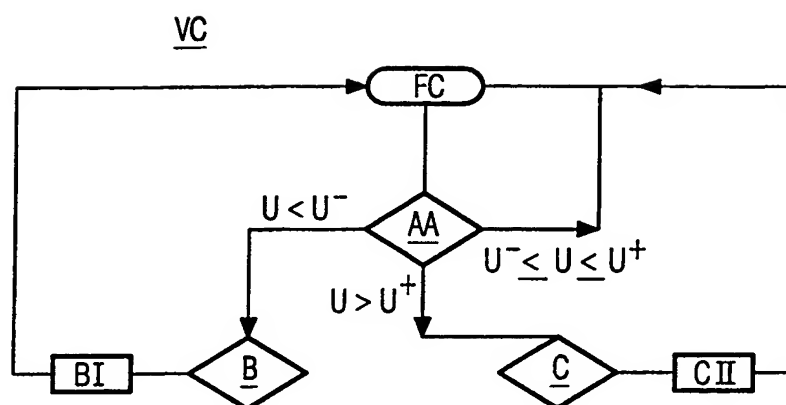


FIG. 3

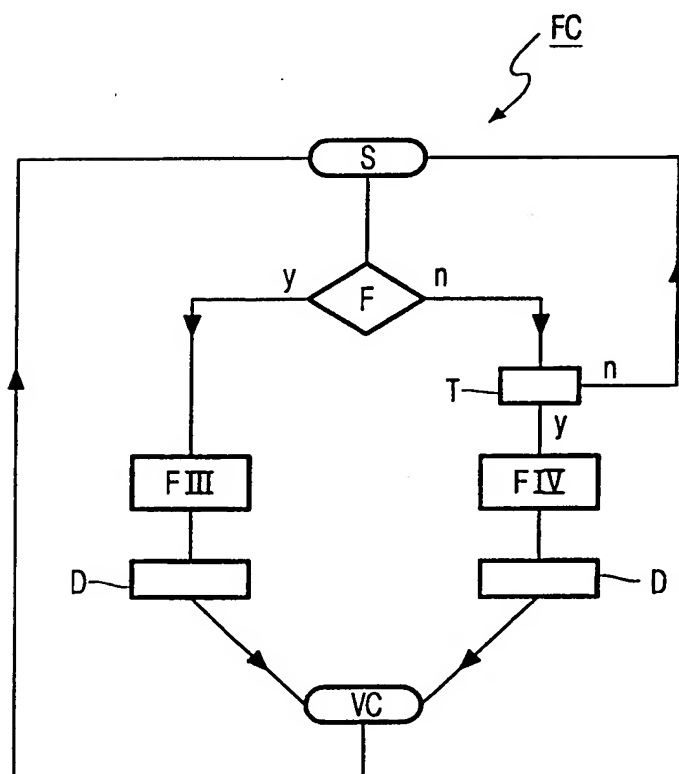


FIG. 4

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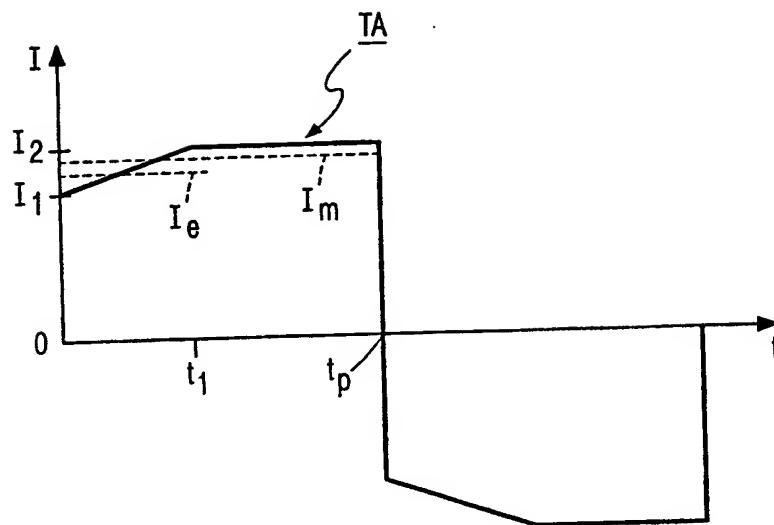


FIG. 5

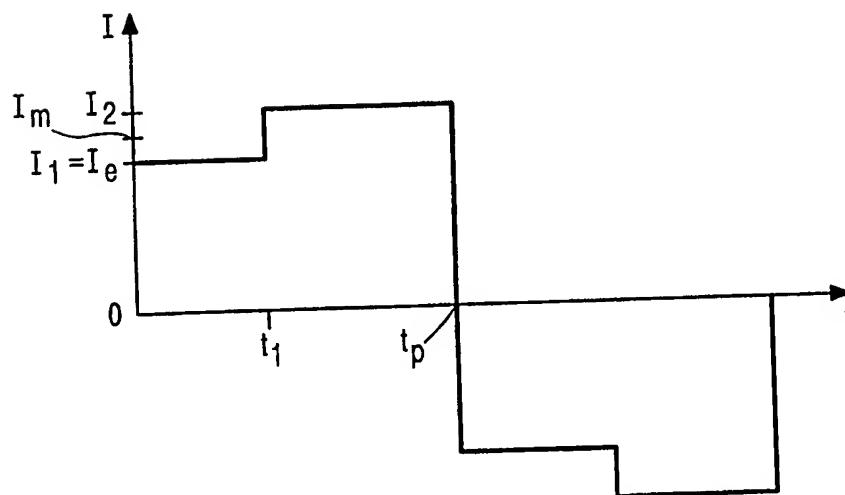


FIG. 6



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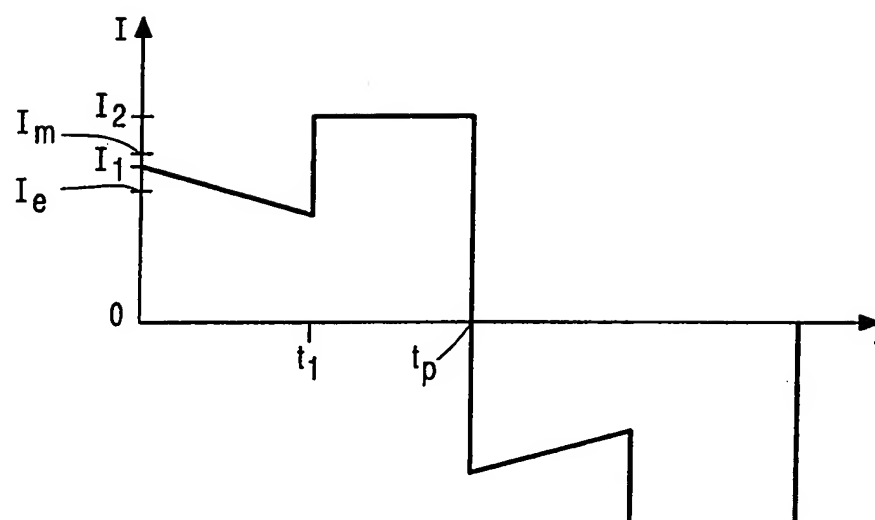


FIG. 7

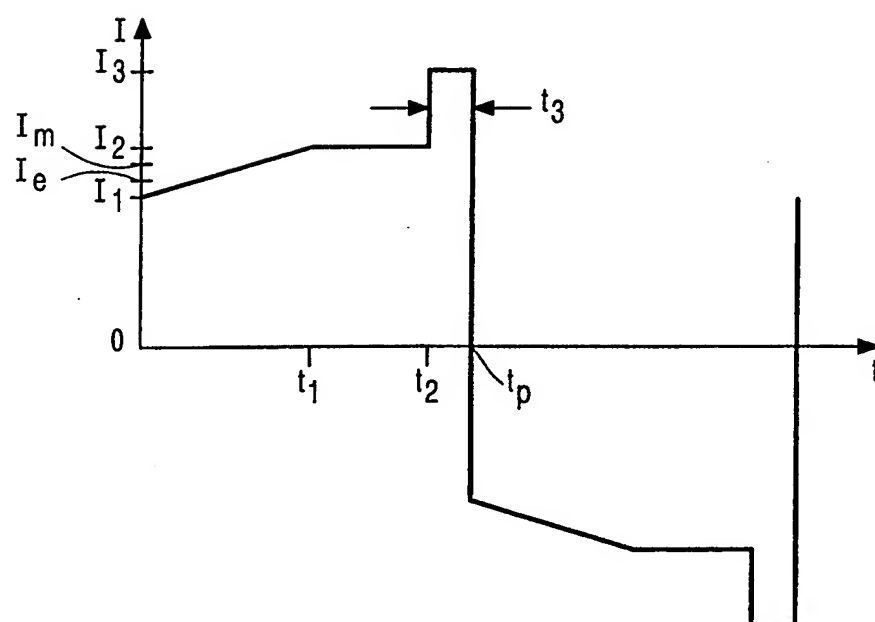


FIG. 8

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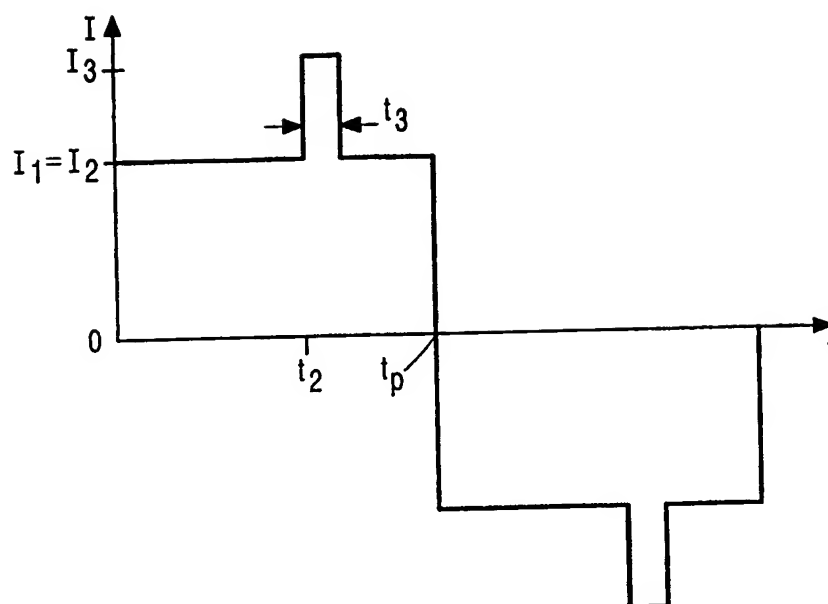


FIG. 9

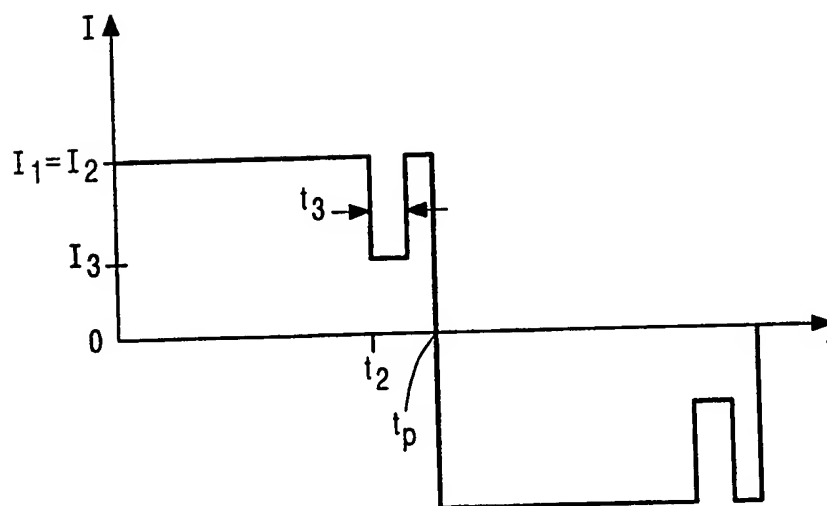


FIG. 10

## INTERNATIONAL SEARCH REPORT

Int. l. Application No

PCT/EP 99/09352

**A. CLASSIFICATION OF SUBJECT MATTER**  
IPC 7 H05B41/292

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 H05B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
P, X	EP 0 944 294 A (MATSUSHITA ELECTRIC IND CO LTD) 22 September 1999 (1999-09-22) column 11, line 23 -column 19, line 17; figures 6-10	1,7
A	US 5 583 396 A (WAKAMIYA MASAYUKI ET AL) 10 December 1996 (1996-12-10) abstract; figures 1,2	1
A	EP 0 825 807 A (MATSUSHITA ELECTRIC IND CO LTD) 25 February 1998 (1998-02-25) abstract; figures 1-6	1
A	EP 0 713 352 A (MATSUSHITA ELECTRIC IND CO LTD) 22 May 1996 (1996-05-22) page 7, line 50 -page 17, line 43; figures 1-16	1-6
	-/-	

☒ Further documents are listed in the continuation of box C.☒ Patent family members are listed in annex.

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Date of the actual completion of the international search

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23/03/2000

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# INTERNATIONAL SEARCH REPORT

International Application No

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## C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	<p>WO 95 35645 A (PHILIPS ELECTRONICS NV ;PHILIPS NORDEN AB (SE)) 28 December 1995 (1995-12-28)</p>	
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Information on patent family members

International Application No

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